Entergy

HEAT RATE
TESTING PROCEDURE
for
FOSSIL FIRED UNITS

Approvals:

T. W. Schmotz Director Plant Support

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Approved: 6/00

1.0 INTRODUCTION

The purpose of this procedure is to provide a standard for heat rate testing methods, test instrumentation requirements, frequency of testing, and test administration and reporting. The heat rate data generated using this procedure is used for developing the unit Input/Output curve function used by the Energy Management Organization (EMO) to economically dispatch the Entergy fossil generating system.

It is recognized that the heat rate of a unit varies with changes in ambient conditions, as well as the condition of the boiler, turbine, condenser, feedwater heaters, and other equipment. This procedure provides a consistent process for the development of an Input/Output curve at constant ambient conditions, (Base Input/Output Curve). The Base Input/Output Curve will be updated on an on-going basis to reflect changes in cooling water temperature (for once-through units) or ambient wet bulb temperature (for cooling tower units).

The Energy Management Organization uses a computerized energy management system to economically dispatch all generating units owned and operated by Entergy. Individual unit incremental cost curves are one of the basic components of the economic dispatch process. Incremental cost curves are derived from the base Input/Output relationship determined by this procedure.

To facilitate the use of this procedure you will find included in the Appendix a Process Flow Chart providing a graphical overview of the basic steps of this procedure. Organizational responsibilities are shown on the chart as well. Three Key Process Indicators and one Quality Indicator are also indicated on the chart to aid in the tracking and control of the functioning of the overall heat rate testing process.

2.0 RESPONSIBILITIES

2.1 Plant Support Department

Overall responsibility for the development and administration of this procedure resides with the Technical Support group of the Plant Support department.

Plant Support regional field office personnel shall implement this procedure at their respective fossil power plants and track the Process Flow Chart (See the Appendix.) process and quality indicators. This effort also includes assessing the unit's readiness for testing, scheduling and coordinating the tests with the EMO and the plant, securing the necessary resources, conducting the tests, computing the results, and communicating the results to the Plant Manager and the EMO.

2.2 Plant Manager

Each plant manager is responsible for assuring that the Base Input/Output Curve for each of their units is representative of the unit's current operating performance. The plant manager shall review and approve all proposed updates to the Base Input/Output Curve.

2.3 Energy Management Organization

The EMO shall provide support for scheduling heat rate tests arising from this procedure. Further, the Director – Operations Planning at the EMO or his designated representative shall review and approve all proposed updates of the Base Input/Output Curve**,** determine in concert with the plant support performance test engineer and apply any needed adjustments necessary to meet minimum C coefficient values and load the new base curve coefficients into the Plant PI database.

3.0 DEFINITIONS

Base Input/Output Curve: The mathematical equation relating the amount of fuel heat input (MMBtu/hr) required to produce a unit of net electrical output (MW), adjusted to base ambient conditions. This is a second order least squares polynomial curve fit of the following form:

Input = (fn)Output
Input = A + Bx + Cx^2

Where: Input = MMBtu/hr
x = Net MW
A, B & C = Constants

Base Ambient Conditions: These are the ambient conditions to which the test results are normalized, i.e. inlet cooling water temperature for once-through cooling systems, and ambient wet bulb temperature for units having cooling towers. For this procedure base inlet circulating water temperature is 75 Deg F, base wet bulb temperature is 78 Deg F, and base relative humidity is 50% for units with natural draft cooling towers.

Steady State Operation: Steady state operation shall be achieved when the maximum variation in key parameter readings throughout a load point test are within the limits shown in the table below:

Net MW	+/- 1.0%
Throttle Pressure	+/- 1.0%
Throttle Temperature	+/- 1.0%
Reheat Temperature	+/- 1.0%

4.0 HEAT RATE TESTING PROCEDURE

4.1 Units to be Tested

All System fossil units are included except units on extended reserve shutdown (ERS). Units will not be committed for testing purposes alone, but will be tested when committed to meet system capacity needs.

4.2 Frequency of Testing

Heat rate tests shall be conducted and the unit's Base Input/Output updated under any of the following conditions:

Major Turbine Overhaul. In this case, it is expected that the performance of the unit will be improved, necessitating a test to verify and characterize the new performance.

12,000 to 15,000 Service Hours since previous test or a Maximum of 3 Calendar Years. Tests should be conducted to reflect gradual changes in equipment condition that occur over time.

Sudden Unit Performance Degradation. Tests should be conducted when sudden performance degradation is observed and cannot be corrected in less than 1,000 service hours. Examples of degradation include loss of a high-pressure feedwater heater from service, mechanical damage to the turbine steam path, etc.

Fuel Change. Tests shall be conducted on all burner primary fuels used for more than 1,000 service hours annually. For fuels used less than 1,000 hours per year, an estimate of performance on these fuels shall be acceptable.

Multi-fuel Units - Separately Fired. For units firing more than one fuel type separately, an initial set of tests shall be conducted on each fuel such that the relative performance between the primary fuel and all secondary fuels may be determined. Such tests shall be conducted within 4 weeks of one another. The performance change between primary and secondary fuels determined from these initial tests may be applied to future tests conducted on the primary fuel to estimate performance on secondary fuels.

Multi-fuel Units - Co-fired. For units firing more than one fuel type simultaneously (co-firing), heat rate tests shall be conducted firing the two fuels in the approximate ratio expected during normal operation. If the actual ratio significantly deviates from the ratio reflected in the Base Input/Output Curve for more than 1,000 annual service hours, consideration shall be given to running new heat rate tests at the new fuel ratio.

Changes in Unit Operating Range. When a unit operates outside of its previous operating range, a new heat rate test shall be conducted under the following conditions:

Minimum Capability. A reduction in minimum capability greater than 2.5% of the unit's maximum capability shall necessitate a new heat rate test and Base Input/Output Curve.

Maximum Capability. An increase in maximum capability greater than 10% shall necessitate a new heat rate test and Base Input/Output Curve.

Co-owner Contract Requirements. The frequency of testing required by co-owner contracts may be different from this procedure. In that case, the frequency of testing shall be no less than that called for in this procedure.

Plant Operational Excellence (POE) Heat Rate Deviation. When a unit deviates from it's dispatch heat rate target by more than 3% over a six-month period, a new test shall be conducted.

4.3 Load Points

Tests shall be conducted at the unit's Minimum Load Capability, Maximum Load Capability and at no fewer than six other load points in between. No less than eight valid test points shall be used to generate an Input/Output curve. Additional loads may be tested at the discretion of the test engineer to ensure that the minimum number of valid test points are obtained. All valid test points shall be used to generate the resulting Input/Output curve. Load points causing unusual operating conditions shall be avoided.

4.4 Test Duration

Upon reaching Steady State Operation, the minimum duration of each load test shall be as follows:

Gas Units	30 minutes
Oil Units	1 hour
Gas/Oil Co-fired Units	1 hour
Coal Units	2 hours

4.5 Scheduling of Tests

The sequence, load, and duration of tests should be agreed upon by the test engineer and plant operations. In order to minimize the system effect of heat rate testing, this schedule shall be conveyed to the EMO at least seven (7) days prior to the conduct of tests. Plant operations shall be informed of any schedule changes as specified by the EMO.

4.6 Test Conditions

Tests shall be conducted under normal operating conditions. Auxiliary equipment shall be in or out of service across the load range per the unit's current operating procedures. The unit shall reach steady state operating conditions before the test is started and maintain those conditions through out the test. [See Section 4 Definitions for the specific variation limits allowed under Steady State Operation.] If the unit has been identified as a sliding-pressure unit, it shall be operated per the normal sliding-pressure mode of operation. At the discretion of the plant manager or the EMO, a rated-pressure test may also be performed. It is expected that no testing will be performed at over-pressure conditions for the purposes of generating a dispatch curve. When major pieces of thermal performance effecting equipment (such as feedwater heaters, heater drip pumps, other pumps, valves, etc.) are out of service and will not be repaired within 1000 operating hours, testing should be performed as soon as possible. Testing can be postponed if repairs will be made within 1000 operating hours. A retest should then be performed after the equipment is repaired and restored to normal operation.

To help ease the operational alignment of the unit prior to conducting a load point test, corrections for small deviations in throttle and reheat steam conditions will be allowed under the following conditions:

- For load test points having an average throttle or reheat temperature not falling below design by more than 10 Deg F (i.e. between 1000 Deg F to 990 Deg F), a correction shall be applied to the test gross heat rate and gross load using the unit specific Thermal Kit correction for that temperature. If the test average throttle or reheat temperature falls below design by more than 10 Deg F, a correction shall *not* be applied for that temperature. If the test average throttle or reheat temperature exceeds design a correction shall *always* be applied.

- For load test points having a throttle pressure not falling below the rated throttle pressure by more than 1%, a correction shall be applied to the test gross heat rate and gross load using the unit specific Thermal Kit correction for throttle pressure. If the test average throttle pressure falls below design by more than 1%, a correction shall *not* be applied. If the test average throttle pressure exceeds the rated pressure, a correction shall *always* be applied. Rated pressure is either design or the current normal operating pressure for the unit.

- For cooling tower units, it is recommended the test be conducted when the actual wet-bulb temperature is within 10° of the base temperature.

4.7 Instrumentation

The regional plant support group calibrated instrumentation and data acquisition system shall be used to acquire the following data at a data recording (scan) rate of at least once per 30 seconds:

Fuel gas orifice differential pressure

Fuel gas orifice static pressure

Fuel gas temperature

Circulating water inlet temperature

Wet bulb and dry bulb temperatures for cooling tower units

This test instrumentation shall be calibrated on a routine basis and shall be traceable to the National Institute of Standards and Technology (NIST). Calibration reports shall be documented and maintained as support data.

In-situ unit instrumentation may be used for the following process measurement points at a data collection rate of at least once every 5 minutes:

Gross generation

Station service

Main steam temperature

Main steam pressure

Hot reheat temperature

Condenser backpressure

Barometric pressure (only one reading per load point test required)

4.8 Fuel

4.8.1 Fuel Flow Measurements

Gas Orifice Plate: Orifice plates are the recommended current standard for gas measurement. Extreme care should be exercised to re-center the plate in the fuel line if it is pulled for inspection or maintenance.

Gas Metering Runs: This procedure is not intended to set standards for gas metering runs. The American Gas Association (AGA) metering run standard is recommended to reduce metering uncertainty, *Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids, AGA Report No.3, PART 2 Specification and Installation Requirements (1991)*. AGA procedures require the use of flange taps across a flat plate orifice to measure the differential and static pressures produced by the flowing fuel.

Oil: Oil flow measurement shall be taken using the Continuous Emissions Monitoring (CEM) calibrated oil flow meters. These are calibrated yearly as required by CEM regulations and no other calibrations are required.

Coal: The recommended method of coal flow measurement is to use weigh chain calibrated coal feeders. The feeder calibrations shall be performed within four weeks of the test.

4.8.2 Fuel Sampling

Gas: A minimum of one (1) sample of fuel gas shall be taken ~~at~~ approximately half~~-~~way through each load test. A constituent analysis of the gas sample shall be conducted by independent laboratory or an Entergy owned laboratory or calibrated test chromatograph. Plant and gas supplier chromatographs are not to be used to determine constituents or heating value. Report deviations between the lab analyzed sample results and the plant and gas supplier analyses to the plant for corrective action.

Oil: A minimum of one (1) sample of fuel oil shall be taken ~~at~~ approximately half~~-~~way through each load test. The determination of heating value and specific gravity shall be performed according to ASTM codes by an independent laboratory or by an Entergy laboratory.

Coal: A representative sample of coal burned during each heat rate test shall be taken by one of the two following methods:

a) Automatic Sampler: One composite sample shall be taken per silo fill.

b) Manual Samples: Two hourly composite samples shall be taken at the operating feeders. The sampling rate shall be one feeder every five minutes.

All coal samples shall be placed into airtight storage containers immediately after sampling to prevent moisture loss and therefore preserve the as fired moisture content of the samples. Bulk quantity samples shall be statically split into smaller representative samples for lab analysis using a sample riffler. A proximate analysis (which provides the percent by weight of moisture, volatile matter, fixed carbon and ash of the coal) and a higher heating value determination of the coal sample shall be performed according to ASTM codes by an independent or plant laboratory.

4.9 Power Measurement

Net power output shall be the difference of the observed readings for gross and auxiliary power. Gross and auxiliary power shall be measured using station meters read using one of the following methods:

A. Local Pulse Counter/Timer:

A pulse counter may be used to accumulate the pulses emitted by the watt-hour meter during the test. In general, the average power metered during the test shall be calculated as follows:

Watts = Watts/pulse x Pulses / Time

B. Hourly MWh Readings from the EMO:

To allow fuel readings to be correlated with hourly MWh readings from the EMO, it shall be necessary to synchronize the test stopwatch with the EMO time as well as start and stop the test on the hour.

C. Timed Disk Revolutions:

With this method, a fixed number of complete watt-hour meter disk revolutions (typically the number of complete revolutions occurring during approximately 1 minute) are timed with a stopwatch. The average power output during the 1 minute period is calculated as follows, (Pkh is the meter multiplier found on the face of the watt-hour meter):

Watts = 3600 x Revolutions x Pkh / Seconds

The above process is repeated at a frequency necessary to get an accurate indication of the average instantaneous power output during the test. This will require timing a fixed number of complete watt-hour meter disk revolutions approximately every 5 minutes throughout the duration of the test.

5.0 INPUT/OUTPUT CURVE DEVELOPMENT PROCEDURE

5.1 Review the data for anomalies, stability, etc.

Key test data should exhibit minimum to maximum reading variability within the limits specified for Steady State Operation as specified in Section 4.0 under Definitions. Large standard deviations or data spiking for any given measurement should be investigated to rule out instrument or data acquisition failures. Data errors or unit stability problems that can not be rectified by screening and hand manipulation of the data set shall be cause for a retest for that load point.

5.2 Reduce observed data to averages, totals, etc.

All test data collected shall be averaged or totaled over the duration of the test run *before* it is used in any computation.

5.3 Calculate the fuel flow rate for each load point test as follows:

Gas: Use the average values for the test of the fuel flow orifice static and differential pressure, the fuel flowing temperature plus the test fuel analysis data to compute the average fuel volume flow rate during the test. The fuel gas flow rates shall be calculated based on *Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids, AGA Report No. 3, PART 3 Natural Gas Applications (1992)* and *Compressibility and Supercompressibility for Natural Gas and Other Hydrocarbon Gases Transmission Measurement, AGA Report No. 8 (1992)*. Use AGA supplied computational software, *Gas Orifice Flow Program for Windows* to calculate the volume flow rate in cf/hr. [See section 7.0 REFERENCES for software ordering information.] The volume flow rate *must be* calculated at the same base (i.e. standard) conditions that correspond with the conditions used in the gas analysis (typically 14.73 psia and 60 Deg F).

Oil: Use the average indicated fuel volume flow rate of gal/hr for the test corrected to the same base (i.e. standard) conditions that correspond with the conditions used in the oil analysis.

Coal: Calculate the total integrator reading increase for each feeder for the measured elapsed time of the test. Sum up all of the integrator readings and convert to pounds of coal. Divide the total pounds of coal burned during the test by the total elapsed time of the test to yield the average mass flow rate of coal in lb/hr.

5.4 Calculate the corrected net output (MW), the corrected net unit heat rate (Btu/kWh) and the test fuel input (MMBtu/hr) for each load point test as follows:

Open the supplied Excel spreadsheet and enter the required (averaged, totaled or pre-calculated) data inputs for each load point test.

All corrections and calculations in the Excel spreadsheet are in accordance with the Group 2 corrections specified in the Performance ASME Test Codes 6 and 6A.

5.5 Calculate the second order Input/Output curve fit coefficients resulting from the corrected net output and test fuel input (MMBtu/hr) as follows:

Execute the supplied Excel spreadsheet to generate the I/O coefficients and to create the standard test report for distribution and approval.

6.0 DATA & RESULTS REPORTING

6.1 Required data and calculation results for each load point:

The supplied Excel spreadsheet generates a standard report documenting the primary test data collected as well as the following calculated results for each load point:

Fuel input (MMBTU)
Corrected net generation (MWh)
Corrected heat rate (Btu/kWh)
New base Input/Output curve coefficients

6.2 Reporting

The standard report generated by the supplied Excel spreadsheet shall be submitted to the Plant Manager for review and comments. Upon his approval the plant support field office will forward the report to the Director – Operations Planning at the EMO for review and loading of the new base curve into the dispatch PI database. It is expected that the test report will be received by the EMO within two weeks of the completion of the tests. If the Plant Manager does not approve of the test results then a written report will be filed by the plant support field office with the Plant Manager and the EMO explaining the problems with the test, how they will be resolved, and when the retest will be performed. The plant support field office is responsible for maintaining records of the raw test data and initial calculations. The Plant is responsible for maintaining records of the final test report.

7.0 REFERENCES

A. American Gas Association. Orifice Metering Of Natural Gas And Related Hydrocarbon Fluids, AGA Report No. 3, PART 2, Specification and Installation Requirements. Third Edition, February 1991: AGA Catalog order No. XQ9104.

B. American Gas Association. Orifice Metering Of Natural Gas And Related Hydrocarbon Fluids, AGA Report No. 3, PART 3, Natural Gas Applications. Third Edition, August 1992: AGA Catalog order No. XQ9210.

C. American Gas Association. Compressibility and Supercompressibility for Natural Gas and Other Hydrocarbon Gases Transmission Measurement, AGA Report No. 8. 1992: AGA Catalog order No. XQ9212.

D. American Gas Association. Gas Orifice Flow Program for Windows [software]. AGA Catalog order No. XQ9503.

E. American Society of Mechanical Engineers. Steam Turbines, PTC6-1976.

F. American Society of Mechanical Engineers. Appendix A to Test Code for Steam Turbines, PTC 6A-1982.

To order AGA publications and materials contact Professional Mailing and Distribution Services (PMDS) of Annapolis Junction, MD at (301) 617-7819, fax (301) 206-9789. Please note that Entergy is a member of the AGA and you should receive member discounted prices.

Appendix A

Process Flow Chart

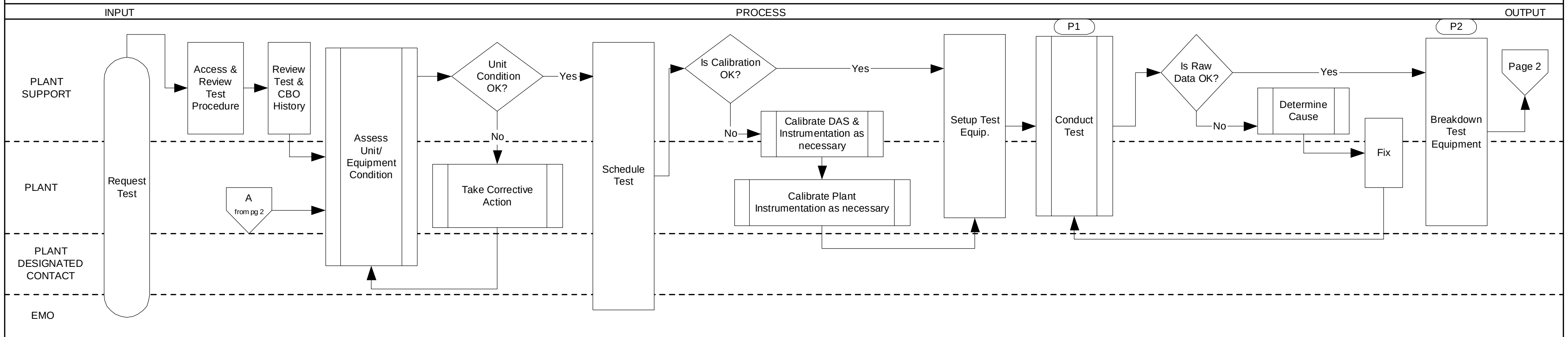
Note: This chart is formatted to fit on two pages of Legal size paper.

QUALITY IN DAILY WORK CONTROL SYSTEM

REV #: 0
ISSUED: 9/1/98
UPDATED:
IHR Flowchart.vsd

PROCESS DESCRIPTION:	OBJECTIVE OF THE PROCESS:	QUALITY INDICATOR:
INCREMENTAL HEAT RATE TESTING	Provide a standard method for developing dispatch curve coefficients	Q1: Total process cycle time

PROCESS FLOW CHART



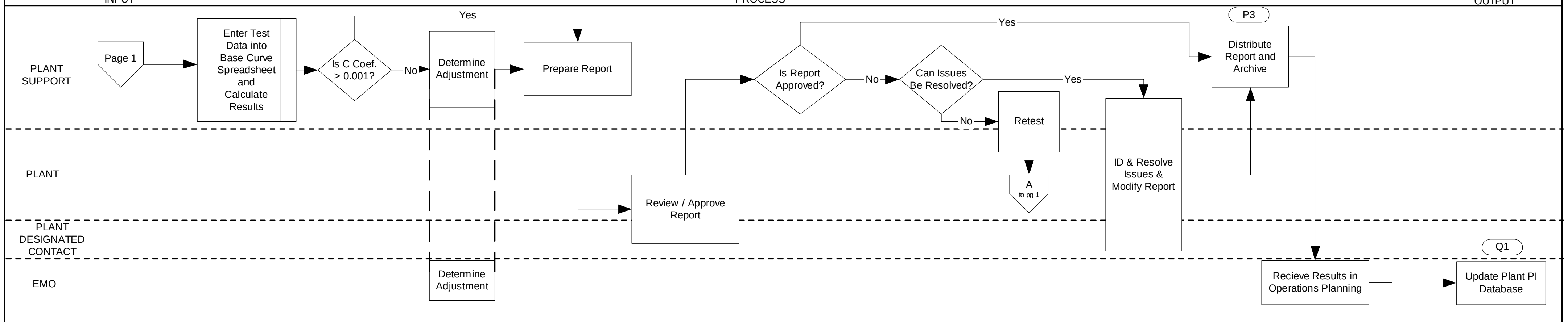
		CONDUCT TEST	BREAKDOWN TEST EQUIPMENT	DISTRIBUTE REPORT	UPDATE DATABASE		REMARKS
KEY PROCESS INDICATOR		P1: DELTA SERVICE HOURS BETWEEN TEST AND TRIGGER SET SERVICE HOURS	P2: TOTAL P.S. MANHOURS NEEDED TO SET-UP AND TEAR DOWN TEST EQUIPMENT	P3: TOTAL P.S. MANHOURS NEEDED TO CONDUCT, ANALYZE AND REPORT THE TEST RESULTS	Q1: TOTAL PROCESS CYCLE TIME (DAYS)		
TARGETS		P1: 12000 TO 15000 HOURS OR 3 CALENDAR YEARS					
CHECKING	**CRITERIA FOR DEVIATION**						
	FREQUENCY	EACH TEST	EACH TEST	EACH TEST	EACH TEST		
	RESPON-SIBILITY	PLANT SUPPORT PERFORMANCE ENGINEER	PLANT SUPPORT PERFORMANCE ENGINEER	PLANT SUPPORT PERFORMANCE ENGINEER	PLANT SUPPORT PERFORMANCE ENGINEER		
STANDARDS OR PROCEDURES		HEAT RATE TESTING PROCEDURE FOR FOSSIL FIRED UNITS		HEAT RATE TESTING PROCEDURE FOR FOSSIL FIRED UNITS			

QUALITY IN DAILY WORK CONTROL SYSTEM	REV #: 0 ISSUED: 9/1/98 UPDATED: IHR Flowchart.vsd	Page 2/2

PROCESS DESCRIPTION:	OBJECTIVE OF THE PROCESS:	QUALITY INDICATOR:
INCREMENTAL HEAT RATE TESTING	Provide a standard method for developing dispatch curve coefficients	Q1: Total process cycle time

PROCESS FLOW CHART

INPUT PROCESS OUTPUT



	CONDUCT TEST	BREAKDOWN TEST EQUIPMENT	DISTRIBUTE REPORT	UPDATE DATABASE		REMARKS
KEY PROCESS INDICATOR	P1: DELTA SERVICE HOURS BETWEEN TEST AND TRIGGER SET SERVICE HOURS	P2: TOTAL P.S. MANHOURS NEEDED TO SET-UP AND TEAR DOWN TEST EQUIPMENT	P3: TOTAL P.S. MANHOURS NEEDED TO CONDUCT, ANALYZE AND REPORT THE TEST RESULTS	Q1: TOTAL PROCESS CYCLE TIME (DAYS)		
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CHECKING — CRITERIA FOR DEVIATION						
CHECKING — FREQUENCY	EACH TEST	EACH TEST	EACH TEST	EACH TEST		
CHECKING — RESPON-SIBILITY	PLANT SUPPORT PERFORMANCE ENGINEER	PLANT SUPPORT PERFORMANCE ENGINEER	PLANT SUPPORT PERFORMANCE ENGINEER	PLANT SUPPORT PERFORMANCE ENGINEER		
STANDARDS OR PROCEDURES	HEAT RATE TESTING PROCEDURE FOR FOSSIL FIRED UNITS		HEAT RATE TESTING PROCEDURE FOR FOSSIL FIRED UNITS			

Appendix B

Example Test Report

Note: This report is generated by the supplied Input/Output Testing Excel workbook template [HRTest.xlt] and is the standard report to be submitted to plant management and the EMO.

HEAT RATE TEST RESULTS
DISPATCH CURVE UPDATE DATA

General Information

Unit	Entergy Unit 2
Test Date	11/2/98
NDC Rating (MW)	216
Service Hours	172,000
Prepared By	John Doe
Test Description	Post-outage Test

Routing

Plant Support Engineer
Plant Manager
EMO

Post-turbine outage test

Unit Condition Summary

This is an example test.

Dispatch Curve Summary

	CW Temp	Wet Bulb	A	B	C	IHR @ NDC
NEW CURVE	75	NA	216.7	8.746	0.00194	9,583
OLD CURVE	84	NA	160.8	9.963	0.00080	10,310

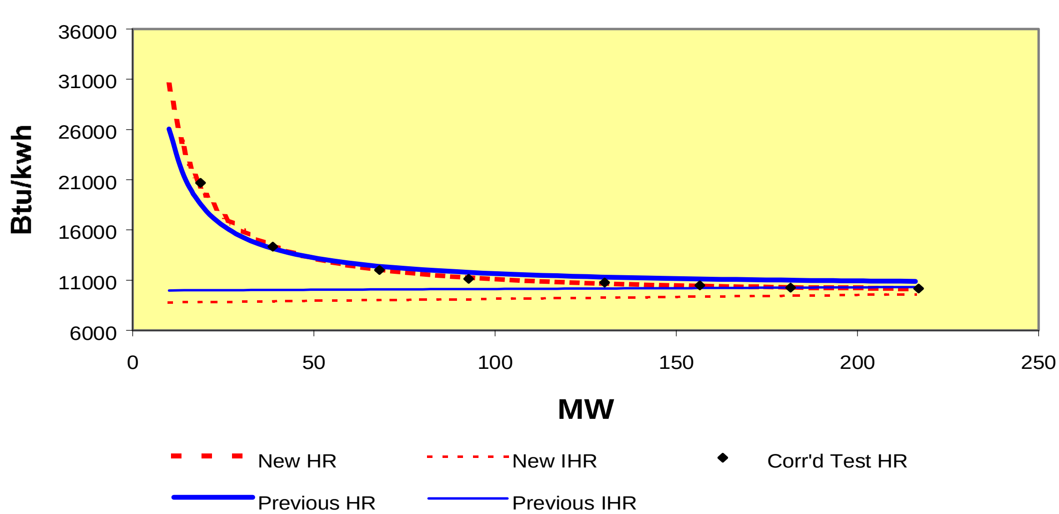
New Curve Heat Rates at Minimum Load and NDC

Ambient Temperature = 75 degF (Cooling Water Temp)

Min Load	**10.000 MW**		
	New	*Previous*	*Change*
Net Unit Heat Rate	30,435	26,055	4,380
Incremental Heat Rate	8,785	9,979	(1,194)

Max Load	**216.000 MW**		
	New	*Previous*	*Change*
Net Unit Heat Rate	10,168	10,881	(713)
Incremental Heat Rate	9,583	10,310	(727)

Base Net Heat Rate vs. Net Load



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HEAT RATE TEST RESULTS

DETAIL SUMMARY

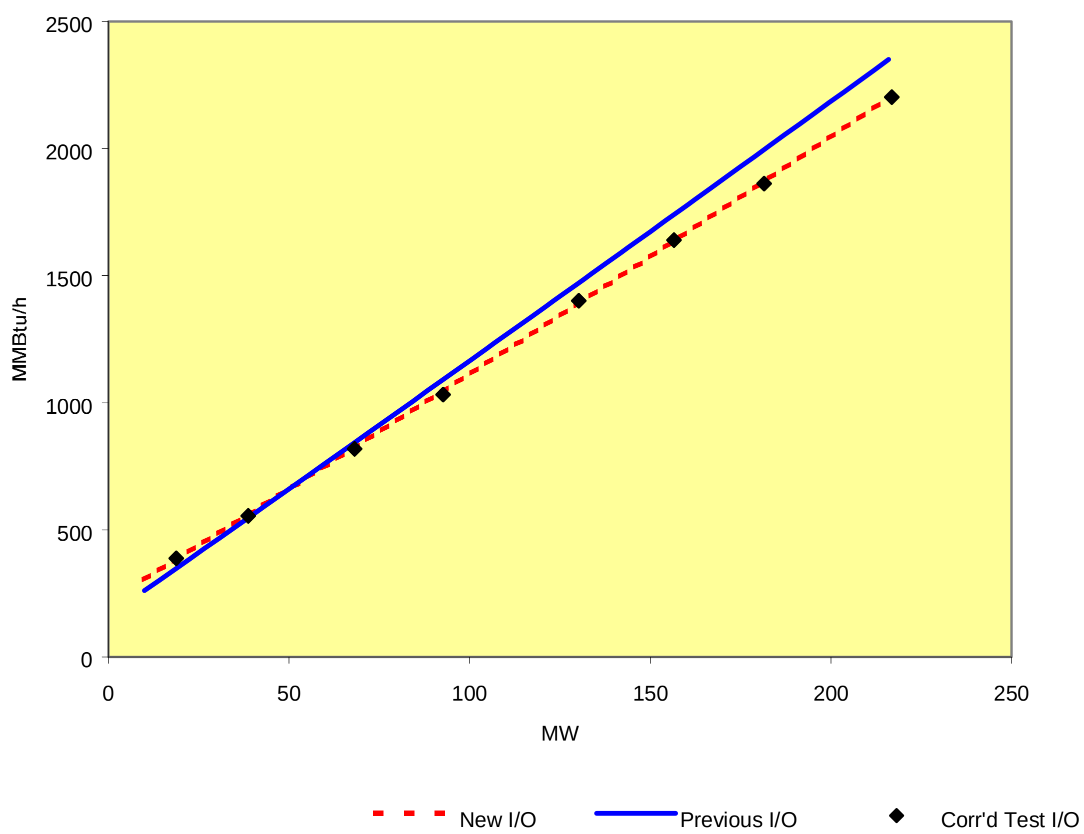
Workbook Settings Summary

Cooling Water Flow Setting	Design Max
Cooling System Type	Open Cooling System
Condenser Pressure Prediction Method	Method 1 - Adjust Test LMTD
Correction Applied for Overpressure Throttle Pressure Deviation Above, (%)	0
Correction Applied for Normal Throttle Pressure Deviation Above, (%)	-1
Correction Applied for Throttle Temperature Deviation Above, (degF)	-10
Correction Applied for Reheat Temperature Deviation Above, (degF)	-10

Standard Conditions

Throttle Temperature	1000	degF
Normal Throttle Pressure	1814.7	psia
Overpressure Throttle Pressure	1904.7	psia
Reheat Temperature	1000	degF
Condenser Design Cooling Water Flow (Maximum)	95200	GPM
Dry Bulb Temperature	75	degF
Wet Bulb Temperature	80	degF
Valves Wide Open Gross Load	228	MW

Base I/O Curve vs. Net Load



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Appendix C

Input/Output Testing Workbook – User Guide

(See separate document file: User Guide.DOC)